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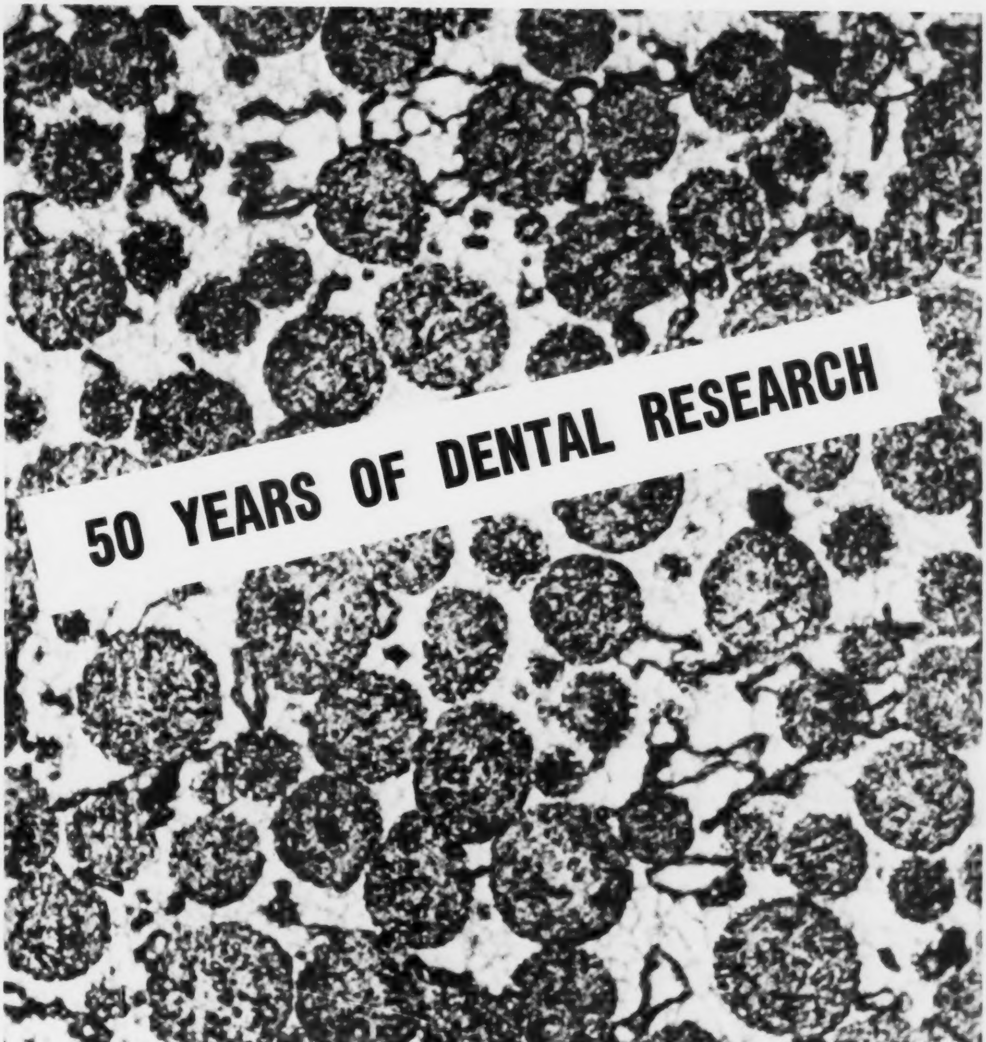

50 YEARS OF DENTAL RESEARCH

U.S. DEPARTMENT OF COMMERCE

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NATIONAL BUREAU OF STANDARDS

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COVER: *Dental amalgams made of such spherical alloy particles as these are gaining rapid acceptance among dentists in this country. The NBS Dental Research Section pioneered in their development—one of its many contributions to dentistry in the past 50 years. (See page 252.)*

U.S. DEPARTMENT OF COMMERCE
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NATIONAL BUREAU OF STANDARDS
L. M. Branscomb, Director

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The National Bureau of Standards serves as a focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. For this purpose, the Bureau is organized as follows:

- The Institute for Basic Standards
- The Institute for Materials Research
- The Institute for Applied Technology
- Center for Radiation Research
- Center for Computer Sciences and Technology

The TECHNICAL NEWS BULLETIN is published to keep science and industry informed regarding the technical programs, accomplishments, and activities of NBS.

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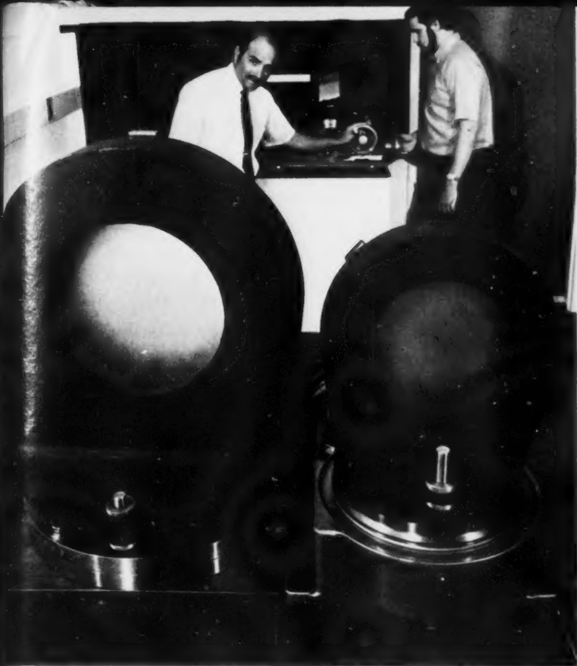


Above: Joseph Reader adjusts slit of pre-dispersion assembly prior to obtaining a line spectrum of a light source (far right, foreground). Left: Joseph Reader (left) and Bruce R. Borchardt adjust grating angle prior to obtaining line spectrum of a resonating gas.

IMPROVED IMAGE FOCUS OF SPECTROGRAPH

PHOTOGRAPHIC LINE IMAGES OF ATOMIC SPECTRA are used by atomic physicists to determine electron energy levels of atoms. The precision and accuracy of these energy measurements depend to a great extent on the quality of the photographic images produced by a spectrograph.

A modified spectrograph at the NBS Institute for Basic Standards produces almost blur-free images. Joseph Reader suggested the modifications and incorporated them in a Czerny-Turner type of spectrograph.[1]

This spectrograph operates on the general principles of mirror reflection and grating dispersion. Light emitted by an electrically excited gas of the element under study enters the spectrograph through a beam defining slit. The light strikes a concave mirror and is reflected back at a small angle to a diffraction grating. This grating not only splits the light beam, but also reflects it onto a second concave mirror, usually identical to the first, which in turn focuses it onto a photographic plate. In most spectrographs the rays of light that form the image do not impinge at the same spot, causing image blur and elongation. In a plane grating spectrograph, the blurring takes the form of image flare (coma) and image lengthening (astigmatism).

The design of the NBS spectrograph was based on an extension of the theory of the nature of coma aberration carried out as part of this project. The accuracy of the theory was checked by means of a computer calculation in which 81 individual rays were traced through the spectrograph, from slit to final image of spectrum line, to directly determine the image quality. The analytical theory and computer calculations were in excellent agreement. The resulting design uses a slightly larger radius of curvature in the first mirror than in the second, giving images with no observable coma and greatly reduced astigmatism.

The spectrograph is now being used by the NBS Spectroscopy Section for accurate wavelength measurements of the spectra of several elements and for the investigation of fine details (hyperfine structure) of selected spectral lines. The data will provide basic information to scientists studying solid state properties of crystals, atomic interactions in both outer space and laboratory controlled environments, and atmospheric conditions for radar detection.

[1] Reader, J. Optimizing Czerny-Turner spectrographs: A comparison between analytic theory and ray tracing, J. Opt. Soc. Am. **59**, No. 9, 1189–1196 (Sept. 1969).

Diagram of NBS improved spectrograph that provides extremely well defined line images of a resonating gas.

FEDERAL STANDARDS POLICY PROGRAM*

I understand that although your organization is particularly concerned with the application of standards, most of you are also involved in standards development. Therefore, since the standards-making process is very much on my mind, I am going to address myself primarily to that area of our mutual concern.

I learned about standards the direct way—by working in the field. Some of my most valued experiences have come from my involvement with people in industry concerned with handbook materials, specifications, and standards.

One important part of my job in the Department of Commerce is to strengthen the efforts already underway to improve the development and application of standards, and further increase their value to the Nation.

As the pace of technological change continues to accelerate, and as our society becomes ever more dependent upon man-made products and systems, the importance of standards increases. They have become more complex, more difficult to develop and apply, and more essential to economic and technological progress than even Mr. Hoover foresaw when he first focused attention on standards during his days as Secretary of Commerce.

I recognize eight different ways in which standards are used. First, standard materials and dimensions make it possible for manufacturers in widely separated parts of the country to make components for an assembled product which can be sold and serviced anywhere. The result is a reduction in the cost of manufacture, and a simplification of the marketplace.

Second, standard practices, coupled with standard materials and dimensions, regulate operations and serve as a means of communication from one man to another—from one industry to another—and from one time to another. Thus, they help to avoid confusion in a job market which more and more resembles a game of musical chairs, and in an economy where many levels of technological sophistication may exist side by side.

Third, standards serve as a communication channel between generations. They aid the engineering graduate and his new employer. Although the engineering schools are providing their students with a much sounder base in science and mathematics, many a young engineer enters his first job with a woeful lack of understanding of practical requirements. Standards can help to bridge this gap between school and job.

*Excerpts from an address by Assistant Secretary of Commerce for Science and Technology Myron Tribus, before the Standards Engineers Society's Annual Convention, Washington, D.C., Sept. 16, 1969.

In a recent address to the Bureau staff, NBS Director Lewis M. Branscomb stressed the importance of science and technology in the Department of Commerce, and the role that the National Bureau of Standards plays as an integral part of the Department. The chart on page 264 shows the agencies that make up the Department of Commerce, and their contributions to achieving the Department's mission: ". . . to foster, serve, and promote the Nation's economic development and technological advancement."

Fourth, standards not only determine how a product is built, but fifth, they also establish the conditions for acceptance by the purchaser—an important consideration for the engineer who designs the product, the businessman who manufactures it, the distributor who must process it through the marketplace, and the consumer himself.

Sixth, standards help to define the obligation of the designer to the manufacturer; and of the manufacturer to the thousands or millions of users whose individual habits are unknown to him.

Seventh, standards serve as a kind of guarantee to the buyer that he is getting fair value for his money.

The final cost of any product is mostly determined by the tolerances we accept in dimension, composition, uniformity, and performance. The closer we come to zero tolerance, the greater the cost to the manufacturer. There is always a trade off between tolerance and performance. Sometimes the trade off is between tolerance and cost of assembly. For an example, I would point to the housing industry which urgently needs to re-cast its approach to standards if it is to reduce costs.

The famous Bouwcentrum in Holland began with a concern for housing standards. They recognized that if dimensional standards could be more tightly controlled, the cost of on-site construction could be diminished. In the Netherlands this has led to reductions in the costs of materials, components, designs, and labor, and to a more rational approach to construction—an approach which has brought benefits for labor, builders, and buyers alike. What the Dutch have done, we certainly can do.

Eighth, standards which are properly drawn and applied provide an orderly framework in which technology can grow in an optimal way; they permit technology to serve the Nation with maximum efficiency and dependability.

There is also a ninth way in which standards can be used—a use which in my view is immoral and often illegal. I refer to the use of standards as a weapon in unfair competition. Some managements have tried to use this approach to gain an advantage over their competitors. We have also seen this weapon used unfairly in international trade. Our Government is seriously concerned with these non-tariff barriers to free trade which freeze us out of foreign markets, while we preserve in our boundaries the largest free market the world has ever known.

Standards can also carry penalties. If a standard is too rigid it can interfere with the development of new technology or new products. If it is poorly written or obsolete it may cause us to optimize around a concept which may have been right to begin with, but which has become invalid due to the introduction of new technology.

One of the problems is that standards writing is a slow and laborious process. Technological change is occurring with almost bewildering rapidity, and is continuing to accelerate, whereas the development of standards is time-consuming and difficult to expedite. We must learn to accelerate the processes of standards development or we shall fall hopelessly behind.

Another problem of growing seriousness is that the consumer or other user is not always properly represented in the standards-making process. And it is important that qualified people who are willing to serve on standards-making bodies to represent the consumer or user interest do so.

I'd like to issue a challenge to you who are so deeply involved in standards: find ways to guarantee proper user representation in the standards-development process, and look after his interests in standards application. There are few greater services you could render your country, your company, or your family.

In considering the broad range of problems in the standards area, I would pose two questions. How can we improve the climate for standards? How can we strengthen the standards-making process?

Improving the Climate for Standards

When we seek to improve the climate for standards, we have to start where decisions are made—at the top. With the exception of a comparatively few companies in a few industries, the development of standards and the specific problems of standards applications have not involved top management to the extent that is needed. As a result, those concerned with writing standards are often handicapped in a variety of ways. They may have insufficient manpower and an inadequate budget, or they may not have access to necessary information about company or industry economics. In other instances, they may be limited by unrealistic restraints; for example, top level insistence on a standard specification which would offer short-term advantages to the company, but would stifle innovation.

To remove these hindrances, we need better communications between the technical people and the top decision makers about the problems and benefits of standards. Once a manager becomes convinced that standards affect production, marketing, profits, his company's reputation, and the future of his industry, his interest and involvement in standards are assured.

We also need to educate the public as to the function and importance of standards development. Comparatively few laymen understand the important role that standards play in providing dependable products and services. Consequently, until recently, they have been apathetic about standards. Only on occasion does a question of safety or product reliability bring the subject briefly, to the fore—in automotive safety, for example. The situation has been made worse by the fact that many standards are several times removed from the consumer, and may be highly technical in nature.

Two possibilities for improving this situation occur to me. First, when companies or industrial associations prepare public relations or advertising material about prod-

ucts and services, they might include references to key standards which safeguard consumer interests. The cumulative effect would be very helpful in educating consumers as to the importance of standards in everyday life, and in demonstrating the manufacturer's interest in consumer welfare.

Second, for the benefit of interested consumers, as well as for writers and editors who disseminate the news, it would be helpful if standards-making bodies would issue two types of written standards: the usual technical document, and an abstract—much simplified—written in layman's language. The abstracts would serve two purposes. They, too, would help to inform the public; and they would stimulate intelligent consumer interest and participation in the standards-making process. This would open up channels for concerned consumer input.

Strengthening the Standards-Making Process

Turning now to the problem of strengthening the standards-making process, we should begin by recognizing a fundamental fact: standards are a key to technological, economic, and social progress. If we accept this judgment, we will give standards the priority they deserve.

The second step should be the realization that our technology cannot advance satisfactorily if we rely only on traditional materials, designs, or methods. Standards which call for specific materials, designs, or methods tend to freeze inventiveness and innovation, and impede progress. If the space program had been dominated by such standards, we would never have put a satellite in orbit, let alone landed two men on the Moon. Yet some of our industries today are being held back by obsolete, restrictive standards and are suffering for it—along with their customers, their stockholders, and the economy as a whole. To unleash the full power of scientific and engineering knowledge, we need performance standards based upon the most precise engineering data available.

The third step is to recognize the growing interdependence of the scientific and engineering disciplines, and of the industries which they have made possible. At one time, a typical standard affected only a very narrow technological area. In an advanced technology such as ours, industries interact in a complex way, and many of the standards which underlie their practices and products interact, also. Without in any way undermining the independence of the voluntary standards organizations, we need to find a way to coordinate standards. Each standard should be considered a part of a total system of standards, contributing to and compatible with those which interface with it.

The fourth and final step I would recommend concerns international standards. In the years in which we enjoyed a comfortably favorable balance of trade, especially in the post-war years when our products dominated world markets, we could refrain from participating in the development of sound international standards without suffering serious consequences. But that time is past.

In the future, if we want to strengthen our competitive position in world markets, we must carry our share of the burden of international standards making, and reap our share of the benefits. Otherwise, we may find ourselves virtually barred from competition in areas where standards were arrived at without our participation.

In closing, I would like to say a few special words about safety standards. It is not just a newspaper catch phrase to refer to this period as "the day of the consumer." Buyers are affluent, and they have many choices. They are better educated. They read the newspapers and they watch television. They are forming opinions, and in the days ahead their voices will be heard.

An informed body of consumers wants performance, quality, safety, and reasonable prices, just as consumers always have. But whereas yesteryear's consumers were content in the main to express their dissatisfaction at the cash register, today's consumers are just as likely to protest by mounting a crusade to seek government protection.

Their particular "thing" is safety. They do not want to be shocked, burned, scalded, wrecked, stabbed, pinched, or poisoned. They consider that product safety is their right, and the courts, increasingly, seem to agree with them.

That puts you, the standards engineer, on a pretty uncomfortable spot. When the question is asked: "Am I my brother's keeper?" The answer has to be, "Yes," but you often have the responsibility without the authority.

That may be the weakest point in the system, but it may also be the best approach to at least a partial solution. I said at the beginning that the chance to talk with you had personal meaning for me. Now I want this afternoon and this message to have personal meaning to each and every one of you.

You, more than any other man in your organization, have the knowledge to put your finger squarely on the hazards in your company's products. It may take courage to buck Operations or Sales; it may mean putting your job on the line. But if I know top industrial management in this country in this year 1969, you can't go wrong mounting your own in-house crusade for safety. Remember, the courts and the law are increasingly on the side of safety. Responsible management knows this. You should be the first to respond to the new industrial commitment. If you fail, someone else will pay. Remember that—it's your job. And if I know the consumer—and the mood of Congress—your company can't go wrong in backing you.

It is easy to get lost in the intricacies of standards development and application, but maybe we can learn a lesson from an old cabinet maker I talked with one day in upstate Vermont. When I asked him how he produced such beautiful furniture, he answered: "Well, it's not so hard when you know how. I take the right wood, and I treat it right, and then I make whatever I'm making so's I wouldn't be ashamed to use it myself!" We might approach standards making in the same way.

CORROSION PERFORMANCE OF TITANIUM IN SOIL

ALTHOUGH THE CORROSION PERFORMANCE OF TITANIUM in the atmosphere, in seawater, and in other environments is well documented, the corrosion performance of titanium in soils is not. This anomaly may be attributed to the emphasis on titanium as an aircraft or missile material. However, Bureau scientists [1] have collected data on commercially pure titanium specimens which indicate that this metal can successfully be used as an underground material.

Corrosion scientists B. T. Sanderson and M. Romanoff of the NBS Institute for Materials Research have reported progress on their continuing investigation on the performance of titanium in soils. Specimens removed from six soil sites after eight years underground revealed remarkable resistance to corrosion. These investigators attribute the mechanism that provides titanium such excellent corrosion resistance to the formation and maintenance of a stable and passive oxide surface film. The protective oxide film evidently is maintained underground, even in very poorly aerated soils.

In studies such as these, the extent of corrosion is determined by weight loss measurements and depth of maximum pits. No significant weight losses and no evidence of pitting or other forms of corrosion (metal attack or stress corrosion cracking) were observed on the specimens of titanium. However, on carbon steel specimens, which were included as a reference material, weight loss was as much as 13 kg/m^2 (43 oz/ft^2) and in two specimens maximum pitting resulted in perforation of the pipe wall. The investigators also noted that welds on the titanium and the weld heat-affected zones were equally as corrosion resistant as the parent titanium metal.

The excellent corrosion resistance of titanium in soils is illustrated by the specimen at far right. Control specimens of carbon steel show the corrosivity of soils at five test sites after 8 years exposure underground. Left to right: Carbon steel exposed in A, sandy loam; B, loam; C, clay; D, sand; G, tidal marsh; and titanium exposed in G, tidal marsh.

The titanium specimens are 4.8 cm by 30.5 cm (1.9 in by 12 in) tubes with 0.10-cm (0.038 in) thick walls. The tubes were fabricated from high strength, commercially pure titanium sheet that had been hot rolled, annealed, pickled, and seam-welded by the tungsten inert-gas process. The carbon steel specimens were pipe with 0.37-cm (0.145 in) thick walls and the same exterior surface areas as the titanium tubes. As a precaution against internal corrosion, the ends of all specimens were sealed with rubber caps.

Selection of carbon steel pipe as a control is based on the experience of NBS since 1922 in evaluating the corrosivity of underground materials in different soils. With carbon steel as the reference material, the soils of the six test sites could be correlated with those of 128 sites in which NBS has previously conducted extensive studies.

The six test-site soils included an alkaline sandy loam (Toppenish, Wash.); a well-drained loam representative of the majority of well-developed soils of the Eastern U.S. (Loch Raven, Md.); a poorly-drained, heavy plastic clay (Cape May, N.J.); a well-drained, loose sand (Wildwood, N.J.); and a poorly-drained marsh soil with high sulfide concentration (Patuxent, Md.).

These soils represent the wide range of chemical and physical conditions found throughout the United States. Chemically, the soils differ widely in the nature and concentrations of soluble salts. The pH of the soils varies from 4.0 to 8.8. Electrical resistivity ranges from 55 ohm-cm, approximately that of seawater, to 30 000 ohm-cm, indicating the extremely low concentration of soluble salts. Physically the soils range from well aerated to very poorly aerated.

[1] Sanderson, B. T., and Romanoff, M., Performance of commercially pure titanium in corrosive soils, Materials Protection **8**, No. 4, 29–32 (Apr. 1969).

NSRDS NEWS

The NSRDS was established to make critically evaluated data in the physical sciences available to science and technology on a national basis. The NSRDS is administered and coordinated by the NBS Office of Standard Reference Data.

Progress in Development of the NSRDS*

We are very pleased . . . to report to you on the progress that we have made in developing a National Standard Reference Data System. This progress is substantial, but the tasks that remain ahead are even larger. The basic framework for the NSRDS is firmly established. It consists of a coordinated network of data analysis centers, each concentrating on a well defined subject, now producing a steady stream of data compilations, critical reviews, and bibliographies. NBS has become recognized as the institution in the Government from which American scientists and engineers can obtain compilations of high quality data on the properties of substances. Cooperation with related activities in other countries is increasing; both governmental and nongovernmental mechanisms have been established to promote such cooperation . . .

Let me first review briefly the objectives of the National Standard Reference Data System. Basically, there are two: First, to provide critically evaluated data to scientists and engineers . . . and second, to upgrade both the quality of experimental practice in laboratories and the reporting of experimental measurements in the public literature. I would now like to discuss each of these goals in more detail.

Since the meaning of the word "data" depends upon who uses it, perhaps a definition now would be timely. The word "data" in the Standard Reference Data System means the results of quantitative measurements of the physical and chemical properties of substances. Such a property might be, for example, the fraction of light of a definite wavelength absorbed by a specific amount of a substance, or the amount of energy released when chemical elements combine to form a new compound, or the ability of a substance to conduct electricity or heat under certain well-defined conditions.

Data such as these are used by most engineers and scientists every day. For example . . . to calculate how much cooling fluid is required, a nuclear power plant designer must know how rapidly heat is conducted through the coating of the uranium fuel element in the reactor core, how rapidly heat is conducted through the shielding material, and how rapidly heat is transferred through the material of the steam generator. For another example, designers of the Saturn rocket had to know accurately how much heat is given off when oxygen combines with hydrogen . . . to calculate the thrust of the rocket. The Apollo capsule designer had to know how much of the sun's energy is reflected by the capsule's external surface . . . to determine how to maintain proper temperature control in the cabin. A chemical engineer must know the aqueous solubilities of the waste materials from a plant . . . to control pollution in the surrounding area. This list of examples could be multiplied many thousandfold.

*This material was excerpted from a statement by Edward L. Brady, Associate Director for Information Programs, NBS, made on May 1, 1969, before the Subcommittee on Science, Research and Development, House Committee on Science and Astronautics, on H.R. 4284, Standard Reference Data System Authorization.

The first place that a scientist or engineer looks for such data when he needs them is a handbook on his own bookshelf. Unfortunately, more often than not, the data that he seeks will not be there. Or, if it is there, its reliability is usually not known. If it is more than a few years old, its accuracy is likely to be unsatisfactory for modern requirements. The costs of using inaccurate data, though certainly enormous, are impossible to identify; they are manifested as inefficiencies throughout all of science and technology.

Compilations of data, carefully evaluated by experts, are needed to minimize these inefficiencies. Such compilations are a normal instrument of technical progress. They are being prepared now, and have been throughout the history of science and technology . . . However, science and technology are moving so rapidly these days that the individual personal initiatives traditionally responsible for compiling data have not been able to maintain pace with the rate of new data appearing in the literature. This is the basic reason why the Federal Council for Science and Technology several years ago called upon NBS to organize and administer a coordinated effort to compile and evaluate the data immersed in the accumulated, and rapidly growing, world's literature. This was the birth of the National Standard Reference Data System.

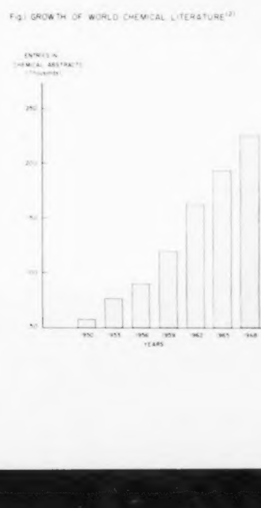
NSRDS is conducted as a decentralized operation of nationwide scope with central coordination by NBS. It consists of a network of data analysis centers and related activities carried on in government agencies, academic institutions, and nongovernmental laboratories. A data center is a group of technical specialists, supplemented by librarians, computer programmers, and other information scientists, who collect technical information in a carefully defined field, then index, abstract, and evaluate the material. The intellectual products of a data center, which demand critical judgment of the highest level of technical sophistication, consist of compilations of critically evaluated data, critical reviews of the state of quantitative knowledge in specialized areas, and computations of useful functions derived from experimental data. NSRDS coordinates existing data evaluation and compilation activities into a systematic program, supplements and expands technical coverage when necessary, establishes standards for quality and for machine processing when required, and provides mechanisms for the distribution of the products. Within NBS, the Office of Standard Reference Data, under the leadership of Dr. David R. Lide, has operational responsibility for managing the program.

Since the program began in 1963, the many people working under the auspices of the National Standard Reference Data System have struggled valiantly to catch up. I am afraid, however, that we have not been able to reduce the stockpile of accumulated literature very much. Of course, we are not as far behind as we would have been if we had not started at all, but we have a very long way to go even to keep up, much less catch up. Some figures will show you the growing magnitude of the problem since 1963 when we began. I will illustrate by using statistics from the literature of chemistry and physics, where most of the data of concern to us appear. The table below shows the number of pages published in two of the principal journals published by the American Chemical Society and the total pages published in all American Chemical Society publications.

Growth of U.S. Chemical Literature [1]

Year	*J. Am. Chem. Soc.*	*J. Phys. Chem.*	*Total Am. Chem. Soc. Publications*
1963	4236	2769	17 486
1964	5947	3997	22 313
1965	6037	4544	23 647
1966	6174	4217	25 717
1967	7416	4800	26 940
1968	7500	5500	30 700

The table shows that the literature output has almost doubled since 1963. We have estimated that the output of quantitative data has more than doubled, since the science of chemistry grows more quantitative every day. There are some indications that the American output is leveling off, but the total world's output shows no such indication. This is clearly revealed in figure 1, which shows the growth in the number of entries in the American Chemical Society's publication, *Chemical Abstracts*, the world's major abstract journal in the field of chemistry. In figure 2 are shown similar data for the field of physics. The American Institute of Physics publishes approximately 35 percent of the world's literature in physics; the journal, *Physical Review*, which is published for the American Physical Society, publishes more original research reports than any other physics journal in the world. The abstract journal, *Physics Abstracts*, is published by the Institute of Electrical Engineers in the United Kingdom.



In the National Standard Reference Data System our present level of effort would be adequate, I estimate, to maintain currency with the literature output of *1953*. The compilation effort of the entire rest of the world is approximately half the U.S. effort, but is growing rapidly.

You may well ask why, if the need is so desperate, more scientists and engineers do not divert their activities to these kinds of projects. The answer is that there is little glamour in this work, little glory in the publication of a compilation of critically evaluated data, and it is more fun to do experimental work in the laboratory. Our program springs from the conclusion that the social pressures on scientists are such that the evaluated data needs of society can be met only if funds are specifically designated for the purpose, adequate to do the job . . .

Now let us consider the second objective that I mentioned earlier—that of upgrading the quality of experimental work done throughout the country. In some of the earliest written material on the Standard Reference Data Program, the improvement of the quality of measurement throughout the Nation's laboratories was stated to be one of the benefits to be obtained from the program. Such improvement comes about because the systematic evaluation process reveals sources of uncertainty in laboratory measurement techniques and also aids in determining the comparative merits of different methods of measurement. If experimentalists are not using adequate techniques or if they are not making an adequate statistical analysis of their data, they soon learn about it.

This aspect of the program was not strongly emphasized because we could not determine in advance how important it was going to be. Experience in the operation of data centers over the past several years has demonstrated that this effect may well turn out to be equal in importance to the availability of evaluated data. I am confident that it will not come as a great shock or disillusionment to the members of this Subcommittee to learn that scientists do not always do the right thing in the laboratory, nor do they always report their work properly. The NSRDS data centers are beginning to get estimates of the fraction of the measurements in their special fields that are reported with sufficient evidence of good technique to be really worth evaluating for other people to use in the future. The figures range from 25 percent to 75 percent.

We are learning what is required in a publication in order that a scientist or engineer who wishes to use a measurement result in the future may have confidence that it was made with adequate consideration of errors and sources of uncertainty. Let me use an illustration taken from the experience of the Atomic Collision Cross Section Data Center operated by NBS in Boulder, Colo. Under the auspices of this Center, a critical review was carried out of experimental data on the ionization of atoms when hit by electrons. The results have been discussed by L. M. Branscomb,* Director of the Joint Institute for Laboratory Astrophysics at the University of Colorado, in a recent paper.[4] He reports: "The authors of this review first set out to analyze the basic experimental methods used. For each type of apparatus used they developed a set of specific criteria that had to be satisfied before one could state that a meaningful measurement had been made. When they compared the papers with the criteria, they found that only 10 percent of the papers in the collection contained even the most rudimentary evidence concerning the essential questions.

"Some papers failed to mention any precautions to prevent (or measure) secondary emission from the electron beam collector, thus nullifying the measurement of the electron current. Others failed to show that the path length of the electrons in the ionizing region was defined. Many failed to demonstrate a meaningful measurement of the target gas density.

"Of the thirty odd measurements of the helium cross section, only six of the papers could be evaluated in terms of the criteria established. The conclusion of the paper is: 'The rare-gas cross sections are generally regarded as well known; the data presented here indicate that this opinion is not well founded unless one considers 20 percent to 25 percent as a small uncertainty.' "

Dr. Branscomb further goes on to say, "It seems likely that about 1500 papers will be written in 1967–1971 containing reports of cross sections for electron collisions. These will cost somebody about $30 000 apiece, or about $45 million. Many of the papers will surely have value, even if they contain no reference data that can be critically evaluated; their primary purpose may have been altogether different, so the cost of the data quoted is relatively small.

"But, to the extent that the work has a measurement of such cross sections as its primary purpose a substantial part of the $45 million might be saved. How? Simply by not doing the work at all unless it is written up in such a way that it can be evaluated, and, therefore, becomes useful."

The situation just described is undoubtedly more dramatic in the particular field of investigation being discussed, but similar, though less serious, situations certainly exist in other fields. Infrared spectroscopy is one; criteria for infrared meaurements developed at the initiation of one of our projects are now being adopted (after slight modification by the appropriate international scientific unions) by analytical laboratories all over the world. We are confident that in all of the fields in which NSRDS is active, an enhanced rate of progress toward meaningful measurement is occurring.

Critical evaluations by NSRDS centers also provide guidance for the experimental programs of the groups in which they are located. You may recall that one of our basic principles of operation is that the data evaluation group must be closely associated with an active experimental or theoretical group in its field, and therefore it must be located in a laboratory environment rather than

*Dr. Branscomb is now Director of the National Bureau of Standards.

in a "scientific information" or library environment. The laboratory director responsible for both data evaluation and experimental measurement programs soon learns to take advantage of the findings of the analysis group; he improves his experimental techniques and he has more information on what substances and what properties it is useful to make measurements.

From the foregoing discussion we conclude, therefore, that the output of NSRDS has both a tangible and an intangible component—tangible in the form of data compilations, critical reviews, and related publications—and intangible in the form of an advancement of the quality of experimental measurement throughout the country. This output comes from twenty-five data analysis centers wholly or partially funded by the NBS Office of Standard Reference Data, plus another dozen or so centers funded by other agencies with which close contact is maintained . . .

The Standard Reference Data Act, Public Law 90-396, gave additional authorities to the Secretary of Commerce, thereby providing new flexibility in the Standard Reference Data System. This Act enables us to operate a publication and distribution program making use of the combined capabilities of the Government Printing Office, the Clearinghouse for Federal Scientific and Technical Information, commercial publishing houses, and professional society publications. In order to take advantage of the authority that we now have to recover a portion of the costs of operation of the program, we shall enter into arrangements with commercial publishers under which a fraction of the selling price of NSRDS publications will be returned to NBS. Commercial book publishers are eager to participate in the NSRDS program. Several manuscripts now in preparation will be submitted to competitive bidding by the publishing community. It is still too early to make a reliable estimate of the financial return to be realized from the sale of documents, tapes, and other products and services. The estimate previously given, that it is expected to be a "significant, but not large," fraction of operating costs, still holds.

When the original hearings on the Standard Reference Data Act were held before this Subcommittee in 1966, Assistant Secretary of Commerce J. Herbert Hollomon testified that it was estimated that the eventual cost of the Standard Reference Data Program would be $18-20 million annually. That figure has now been revised downward to approximately $12 million. The reason for this downward revision is the progress that has been made internationally in developing arrangements to share the effort of producing compilations of critically evaluated data. The establishment of the U.S. program has stimulated interest among scientists and governmental organizations in other countries, resulting in numerous bilateral and multilateral discussions. Possible cooperation has been discussed with scientists from the United Kingdom, France, Germany, U.S.S.R., Japan, Canada, and Poland. Multinational cooperation under the aegis of various international scientific unions has been underway for many years and is expanding under the stimulus of the current interest.

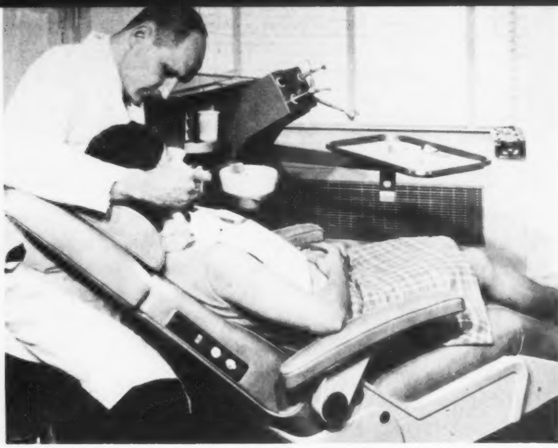
The International Council of Scientific Unions has created a Committee on Data for Science and Technology (CODATA) whose function is to promote international cooperation, to serve as a channel of communication among projects in various countries all over the world, to encourage more scientists to undertake projects of this type, and to make recommendations about needs and priorities to persons responsible for funding such projects in the various countries. In July of 1968, CODATA sponsored a conference held near Frankfurt, Germany, which brought together approximately 100 scientists and government program officials from the major developed countries of the world to discuss on-going activities and the prospects for international cooperation. Channels of communication established at the meeting are now being utilized in efforts to plan and coordinate projects undertaken jointly by American scientists and those of a number of other countries.

The Soviet Union has established a program patterned in many ways after that of the U.S., which they call the "State Service of Standard and Reference Data." Under the auspices of the U.S./U.S.S.R. Cultural and Scientific Exchange Agreement, an exchange of visits is now being negotiated, hopefully to take place later this year. Our present evaluation of current work in the Soviet Union convinces us that the potenial benefit of developing a significant exchange with the Soviet Union is substantial.

The Standard Reference Data Program is one of three areas in which NBS uses the special foreign currency program to promote its interest. A few projects are now active in India and in Israel; many worthwhile projects could be undertaken in Israel if funds were available. Present plans call for an exploratory mission to be sent to Yugoslavia and Poland to discuss projects that might be initiated in these countries.

The recent passage of the Standard Reference Data Act has focused the attention of technical program managers of the various government agencies upon our activities. Program managers from the Atomic Energy Commission, NASA, and the Department of Defense now look to NBS to provide data compilations in areas of general interest to them as well as to the entire technical community. We welcome their interest and seek their advice on priorities. In the future as our program develops, we hope to be able to satisfy a larger fraction of the needs of all segments of the technical community.

[1] Chem. Eng. News, **46**, No. 12, 52 (Mar. 1968).
[2] Chem. Eng. News, **47**, No. 16, 23 (Apr. 1969).
[3] Private communication from American Institute of Physics Headquarters, 335 E. 45th St., New York, N.Y.
[4] Branscomb, L. M., **Is the literature worth reviewing?** Sci. Res. **3**, No. 11, 49–56 (May 1968).



FIFTY YEARS OF D[illegible]AL THE NATIONAL BUR[illegible]

In the Bureau's dental clinic, H. Chandler checks the performance of an experimental tooth restoration in a patient to correlate clinical performance with laboratory data in developing better dental materials and methods.

THE YEAR 1919 MARKED THE BEGINNING OF DENTAL research at the National Bureau of Standards. In the fifty years following, the many achievements of the Bureau's dental research group transformed the practice of dentistry and advanced the profession's objective of better dental treatment for the public.

The initial impetus for the Bureau's dental research program came when the Army requested NBS to test dental amalgam alloys that were proving unsatisfactory. From this request came the realization that scientific data were lacking not only for specific amalgams but for all dental materials. Thus scientific research on dental materials was formally instituted.

Since that time, dental research at NBS has progressed to a broad-based program ranging from studies of restorative materials and instrumentation to studies of basic tooth structure. This research program is carried on by NBS staff personnel, Research Associates, members of the Armed Services Dental Corps, and Guest Workers. The sponsorship of a substantial Research Associate effort in dental research by the American Dental Association for about 40 years has encouraged unusually close rapport among this physical science laboratory, dental manufacturers, and practicing dentists. In addition to support by the American Dental Association, the program has been cooperatively funded by the National Institute for Dental Research, the Dental Research Division of the U.S. Army Research and Development Command, the Dental Sciences Division of the School of Aerospace Medicine (U.S. Air Force), and the Veterans Administration.

First Fifty Years

In the first 50 years the dental research group investigated many problems in dentistry that today have been either eliminated or minimized through its research efforts. For example, research at NBS has resolved some of the more serious problems in restorative dentistry, particularly those pertaining to *amalgams*—a material used in more than 75 percent of all tooth restorations. One problem was the excessive "delayed expansion" of amalgams on hardening. With the aid of an NBS-developed interferometric method, "delayed expansion" was found to be due to gas evolved and entrapped in the amalgam. It was shown that delayed expansion could be eliminated by prevention of moisture contamination of the amalgam during preparation of a tooth restoration.

Pioneer work at NBS on *gold alloys* during 1922 and 1932 placed the casting of dental restorations (inlays and partial dentures) on a scientific basis. Through Bureau efforts exact methods for measuring casting shrinkage of restorations, as well as other physical and chemical properties, were developed. A product of this research is the still widely used MOD* steel die for evaluating precision dental castings.

*A die that simulates a tooth with a cavity preparation extending from the chewing surface down two opposite sides of the tooth.

Until the recent introduction of composite materials, *silicate cements* served as the most widely used material in the restoration of anterior teeth. Bureau studies of these cements have been a significant factor in the development of the high quality cements available today. These studies also demonstrated the great effect of manipulative variables on the final appearance and performance of a restorative.

The very stable and lifelike dentures available today owe much to the dental research staff's studies on *resins* begun in the 1930's. This work established standard methods for measuring the essential physical and chemical properties of resins and explained, in particular, the troublesome problem of dimensional instability.

Commercial production of *composite materials* for dental use is largely due to NBS developments on synthesizing special polymers and reinforcing these with inorganic fillers. Not only have the composites been shown to have a lower solubility than the silicates, but they also have better mechanical properties and a much lower thermal expansion than the resins. Because of these advantages, composites are replacing the silicates and the resins as anterior direct filling materials.

The first advance in high-speed, rotating *cutting instruments* that led to a breakthrough in operative dentistry resulted from this group's research. Today's air turbines, with speeds of 200 000 to 400 000 rpm,

…AL RESEARCH AT …U OF STANDARDS

were prompted by the NBS development of the contra-angle turbine handpiece.

A panoramic *x-ray machine* developed for the U.S. Air Force was specifically designed for rapid surveying and general diagnosis of the oral condition of military inductees. Unlike conventional dental x-ray machines, the instrument takes a picture of the complete dental arch in a few seconds on a film outside the mouth. It currently is in extensive use in military clinics and induction centers and is expanding in use in civilian hospitals and medical offices.

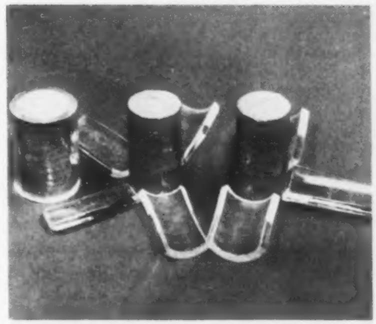
More recently, NBS and Army researchers developed an improved dental *splinting material* for treating fractures of the jaw. This doughlike material, which hardens in 4–7 minutes, replaces the more commonly used archbars without the adverse effects associated with archbars. Tests have shown the new material to have sufficient strength, rigidity, and dimensional stability to function as a splinting material, to aid reimplantation of teeth, and possibly to have other medical applications.

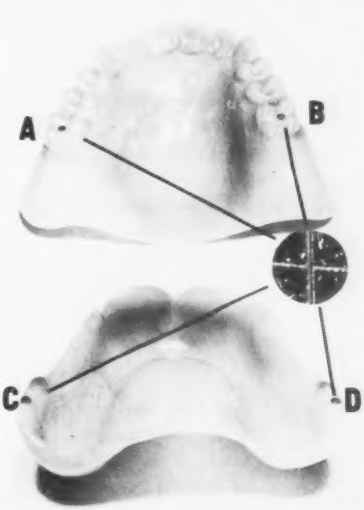
Present and Future

As dental research at NBS enters its second half century, a number of problems remain to be solved. The solutions to many of these depend on a better understanding of the properties of natural tooth structure. For this reason, a major part of the cooperative program is now directed toward characterization of those compounds that make up enamel (the hard outer layer of the tooth) and dentin (the softer mineralized structure beneath the enamel). Such studies will provide a deeper insight into mineralization phenomena in biological systems.

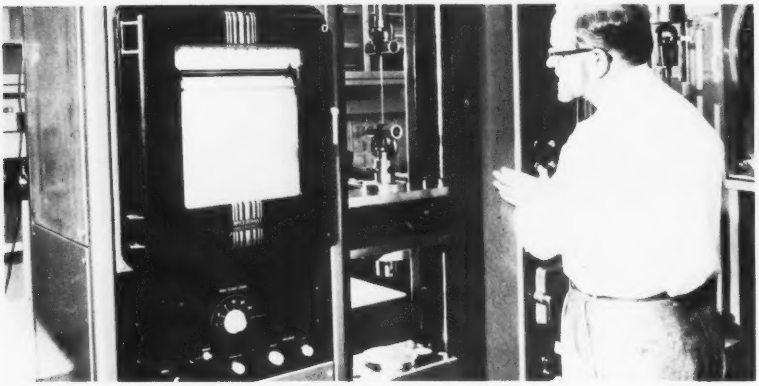
Fundamental to the characterization of dentin and enamel is knowledge of the *crystal structures* of their chief constituents, the calcium phosphates and calcium carbonates. However, the crystal structures for many of these mineral compounds and their derivatives are unknown. At this time NBS researchers are determining some of the more important structures for these compounds. Once determined, the structures will provide a basis for models in describing chemical reactions, crystallization, and the incorporation of carbonate, fluoride, and other compounds in tooth and bone mineral.

In addition to crystal structure analyses, information for predicting chemical reactions is being sought through *solubility studies* of calcium phosphates. Solubility constants, and dissociation constants in some cases, have been determined at various temperatures for several compounds, including hydroxyapatite and whit-





Above: Once a troublesome problem, "delayed expansion" of amalgams was found to be caused by entrapped gas. The force exerted by expansion of two cylinders of moisture-contaminated amalgam broke the glass tubes in which they were packed. Normal, comparatively small expansion of the uncontaminated amalgam locked it tightly in the tube without breaking it. Center: The superior adaptability of amalgams produced from spherical particles (designated 5) is illustrated in a comparison with those produced from irregularly shaped particles (commercial brands A and B) at low packing pressures. Below: Steel pins implanted in the molar area of dentures provide reference marks for measuring dimensional changes of experimental denture base materials from the time the dentures are made through years of service.



G. Dickson determines the tensile strength of a gold alloy specimen in a tensile testing machine to evaluate its mechanical properties.

lockite. Of these, hydroxyapatite has received the most attention, primarily because it is the principal inorganic component of tooth and bone.

As solubility measurements give a direct indication of the thermodynamic properties of a compound, attempts are being made to use solubility data to reduce errors in reported thermodynamic values. The dental research group has prepared a self-consistent set of thermodynamic values for the calcium phosphates based on solubility measurements rather than on the usual calorimetric measurements, which use less reliable heats of dissolution values. Solubility data, when combined with thermal data, should make possible the calculation of standard free energies, enthalpies, and entropies of formation.

Further characterizations of tooth components are being carried out in a study of the *chemical reactivity of the dentinal and enamel surfaces.* At present little information is available regarding the presence or relative abundance of reactive sites—the acid and basic groups at these surfaces. Such data, which the investigators hope to provide in the form of heats of adsorption values, will yield valuable information on the types of materials that will bond at these reactive sites. This knowledge could lead to the development of a suitable adhesive restorative material or a transparent "paint-on" adhesive that would arrest tooth decay in its initial stages.

Another direction of research being taken by the dental program is a determination of the effects of *mechanical forces* on restorative materials and on natural structures. Mechanical forces, such as occur in chewing, are borne by the teeth, restorations, supporting bone, and soft tissues, and must be understood if these forces are to be realistically related to the properties of restorative materials.

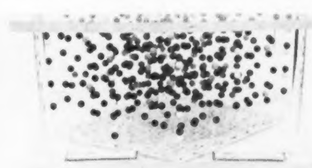
Analyses of mechanical stresses on tissues are being made using rat skin to simulate the mucous membrane that lines the mouth. This membrane, which consists of several layers of tissue, is subject to many mechanical stresses. Stresses such as those from a denture sometimes result in inflammation, and thus a change in the mechanical behavior of the membrane. Such a study is expected to show the effect of inflammation and other metabolic processes on the mechanical behavior of the membrane.

In these experiments, a number of phenomena were found to exist in skin simultaneously, some of which are thermodynamic and others which are viscoelastic in character. The mechanical behavior of rat skin at body temperature appears to be controlled in large part by kinetic processes (rheological) rather than by state dependent processes (thermodynamical). Once each phenomenon contributing to the mechanical behavior of skin has been well characterized over a sufficient temperature range it can be related to the behavior of the various components of skin such as collagen. These separate phenomena will then be assessed in terms of various metabolic, physiological, pharmacological, and pathological factors that affect the mechanical behavior of skin.

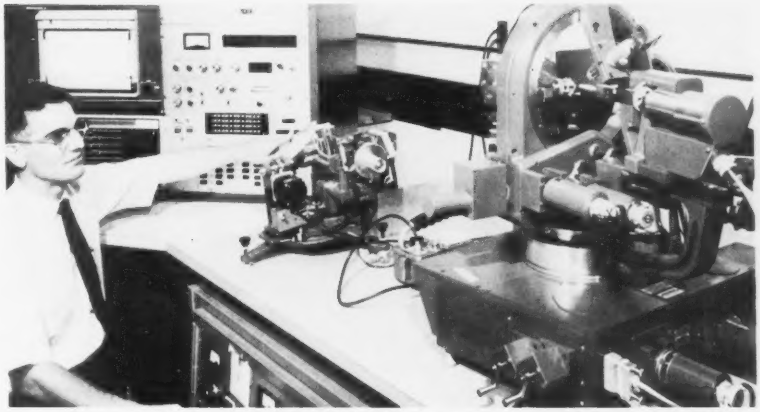
The *thermal expansion* of enamel and dentin is another area of concern because of the importance of this property in the stability of restorations in teeth. Should a difference exist between the thermal expansions of the tooth and the restorative material, the restoration tends to separate from the tooth surface. However, should adhesion be maintained, thermal expansion differences may fracture either the tooth or the restoration if the dimensional changes are not accommodated by the viscoelastic characteristics of the materials.

Results from this study on thermal expansion verify the wide variability previously found in the thermal expansion of dentin. Present objectives are to determine if these variations can be related to differences between teeth, effects of orientation, the viscoelastic characteristics of dentin, variations in the contributions of the organic and inorganic portion of the material to the expansion of the composite, or to other factors.

Metallurgical research in the dental program seeks to develop new alloys or to modify present alloys for use as restorative materials. NBS presently



Composite materials of inorganic filler particles bonded with a crosslinked organic polymer, like the one in this photomicrograph, are replacing silicates and unreinforced direct filling resins as anterior filling materials.



X-ray diffraction equipment such as this operated by B. Dickens is essential to the Section's crystallographic studies of the mineral compounds found in dentin and enamel.

is exploring binary alloy systems combining a base metal and a noble metal (gold, silver, platinum, iridium, or rhodium). The noble metals exhibit many desirable properties for use as a dental material, but have found limited use in industry. For this reason, they have received little attention, and information such as phase diagrams often is either unavailable or unreliable. Bureau research in this area therefore necessarily involves determining pertinent phase diagrams and developing the rudiments of alloy theory as it applies to these metals.

A renewed program of research in dental metallurgy deals with the microstructures of alloys, such as dental amalgam, and how the microstructure is related to strength, carvability, corrosion resistance, setting expansion, rate of hardening, and adaptability. The recent development at NBS of dental amalgams utilizing *spherical alloy powders* has demonstrated the importance of microstructures in controlling alloy properties. The unmistakably uniform size and shape of the alloy particles of these powders enable the researcher to identify the location and relative quantity of each constituent. With a technique developed in the Bureau's Metallurgy Division, accurate measurements can be made of the particle sizes, distance between particles, and percentages of each size. This technique incorporates, a photo-electric cell and a rapid scanning device to measure the relative areas of light or dark regions on a photomicrograph and feeds the results directly to a computer.

The dental research group also is striving to fulfill one of the most pressing needs in dental practice—a *restorative material* that adheres permanently to hard tooth tissues. An inadequate seal between the surfaces of the tooth and the filling material is a common cause for the failure of a filling and results in further decay. The development and use of a strongly adhering restorative material would improve the seal and thus prolong the life of a finished restoration.

Effective *composite resin-silica restorative materials* based on previous research at NBS are being used in dentistry. Bureau researchers are now developing composites of a special x-ray opaque glass filler and a polymeric binder, which now are being evaluated to determine the value of the x-ray opacity to diagnostic and prognostic procedures.

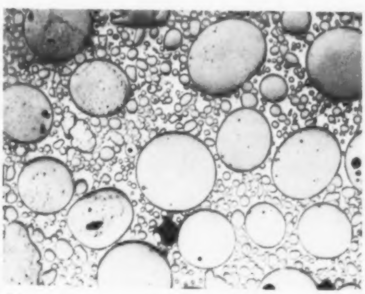
Composite materials for *temporary restorations* are also being developed. One, a zinc oxide eugenol cement containing acrylic polymer, appears promising as a long-lasting temporary restorative. A material serviceable for one to two years is of special interest to the Armed Forces, as it would permit delay of needed treatment until a combatant returned to an area with suitable dental facilities.

In its research on dental restoratives, the dental section is examining the possibility of *grafting* polymers to tooth dentin. The filling material would be a high-molecular-weight polymer attached by covalent bonding to the collagenous component of dentin.

The potential use of *dental liners*, adhesives that bond to the tooth structure and restorative material, is being investigated. These liners would contain groups that react with the calcium of the tooth to form chelates and other groups that could copolymerize with the restorative. Bonding efficiency is being tested on bovine tooth surfaces.

Another study concerns *chemical treatment* of the teeth to increase the adhesiveness of a resin filling. Inorganic solutions, especially the halides, were tested and the strength of the bond at the tooth surface-resin interface was determined. For a cold-curing resin, teeth pretreated with most halide solutions gave adhesions up to eight times stronger than untreated teeth.

Throughout these past 50 years, the dental staff has contributed significantly to better dental treatment for the public. Research activities such as these now underway will bring dentistry still closer to its goal of better dental treatment for the public.



Three-dimensional model of hydroxyapatite used in crystallographic studies in the Dental Research Section. Colored beads define the positions of calcium, phosphorus, oxygen, and hydrogen in this complex molecule, which is the principal inorganic component of tooth and bone.

NEW FINGERPRINT IDENTIFICATION SCHEME

NBS System Simplifies Computer Comparisons

IN CONTINUING RESEARCH ON WAYS of describing fingerprints to be read into a computer for storage and comparison, the NBS Center for Computer Sciences and Technology has developed a new, single-fingerprint classification system. Devised by J. H. Wegstein, of the Center's staff, in research for the Federal Bureau of Investigation, the new method has manual steps, but is easy to use with the help of a computer and promises speedy responses.[1] This method, whose alphanumeric descriptors can be transmitted by teletype, would greatly speed the use of medium-sized fingerprint files. Searches of the central file could be initiated at remote units, such as local police stations, and matches or verification returned within minutes.

A reticle with engraved positioning lines and radials is used to code descriptors for single fingerprints. The ridges lying above the upper intersection are coded 1 (nearest intersection) through 14.

The fingerprint classification system used by law enforcement agencies in this country requires all ten impressions for each subject. A workable single-fingerprint system could make coding easier and faster. The recent single-fingerprint research at the NBS Computer Center has been sponsored by the FBI because of its interest in concise systems using descriptors that are amenable to computer handling. Such a system that is easily used in the field could be of use in the National Crime Information Center—a fast-answering central file on wanted criminals that is located at the FBI.

Some fingerprint systems use descriptors based on topological features, such as gross patterns, core patterns, and ridge counts; these systems are vitiated by poorly inked fingerprints and require extensively trained technicians. Other systems depend on geometric measurement of distances between minutiae—details of the fingerprint. Here the classification obtained is influenced by flexing of the skin and the manner in which the finger is grasped and rolled by the technician making the impression.

Needed is a fingerprint characterization scheme that minimizes these shortcomings and that persons of limited experience can use. The notation should be one that can be readily handled by a computer because full automation will be required when a device reading fingerprints automatically finally is developed.

Coding with a Reticle

Reticles, transparent overlays marked with geometric patterns, have been used in earlier methods of classifying single fingerprints, such as the Jorgensen, Collins, and Battley systems. Mr. Wegstein's method uses a reticle engraved with radial lines that divide the area above a horizontal line into ten numbered sectors. It fits a standard fingerprint magnifying glass for use.

The reticle is positioned for use with a horizontal line on the first continuous ridge above the fingerprint core (its characteristic central part) and parallel to the joint crease below it. As one scans the ridges from left to right above the core, some can be seen to arch unbroken across the horizontal line from left to right. Others start abruptly above the horizontal or split apart from another ridge,

while some end or merge before reaching the horizontal at the right. The reticle is used to assign numbers telling where these events occur.

The number of the sector and the number of the affected ridge (counting upward from the reference ridge) determine the code. For example, if the second ridge above the horizontal line starts in sector four, it is coded as *2s4*. If the third ridge ends in sector 9, it is coded as *3e9*. If the fourth ridge passes through all sectors, it is coded as *4-*. Provision is made also for coding islands, or short sections of ridge.

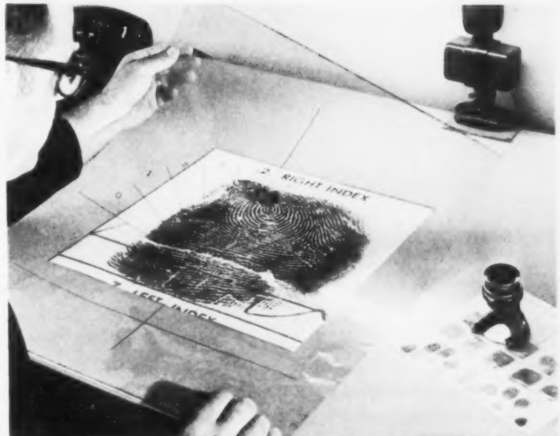
Events occurring in ridges one to fourteen are noted in this manner. The technique for coding a fingerprint is easy to learn and enables a fingerprint to be coded in less than five minutes. The police officer or technician would normally code—give descriptors for—both of the index fingers for either filing or seeking a match.

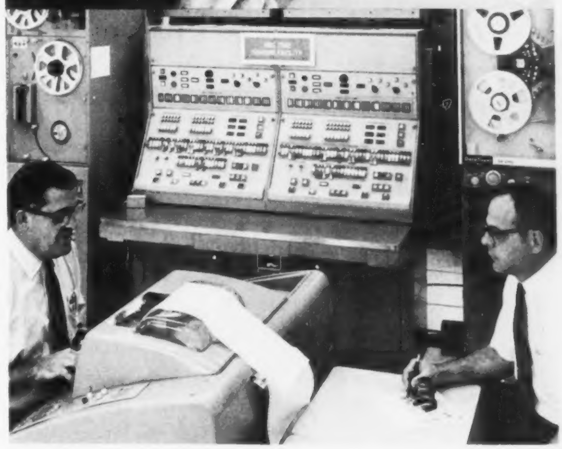
Computer Processing

The codes describing a fingerprint can be communicated to the central computer by means of a remote teletypewriter, or by telephone or radio link to the nearest teletypewriter that is connected to the computer. The computer can then search its file for fingerprint codes that match the incoming one.

A computer program developed by Mr. Wegstein and John F. Rafferty, also of the Center's staff, compares a code submitted for searching against those already on file and computes a score for each comparison. The more alike two prints are the higher the score. If a fingerprint code from the file yields a score above a "match" threshold, the program directs the computer to transmit the identity of the corresponding individual to the remote teleprinter. Manual comparison of fingerprints can then be used for a positive identification.

Remote interrogations of a small experimental file of fingerprint codes have been made. The teletypewriter terminal used is connected by an acoustic data coupler and regular telephone line to the Mobidic computer in the research computer facility.





Above: A new single-fingerprint classification method uses a reticle built into a fingerprint magnifier for coding ridge beginnings, endings, and segments. What a coder sees is demonstrated by the oversize reticle being positioned by Walter Pencak on an enlarged fingerprint.
Below: John Rafferty keyboards descriptors into the Bureau's Mobidic computer as Walter Pencak codes the fingerprint. The computer will identify any fingerprints for which an adequate matching score is obtained.

FINGERPRINTING FROM ANTIQUITY TO THE PRESENT

Fingerprints have been used since antiquity to convey authenticity, as of a monarch's edict, an engraver's art, and (during the past century in the United States) to prevent forgery of commissary orders. Their uniqueness was more fully recognized early in the 19th century.

Sir Edward Henry first used fingerprints in solving crimes; the Henry system has now been in use for over 60 years. It assigns alphanumerical identifications to finger patterns and assembles an identification for the set of ten prints.

Other efforts have used methods of describing single impressions; one was adopted by an International Police Conference in 1923 and others have been studied at Scotland Yard to supplement the Henry system in dealing with latent fingerprints. These are fingerprints left unintentionally—as at the scene of a crime—and hence usually show only part of the pattern, may be smudged, and are from undesignated digits. Single-fingerprint systems have been hampered by the skill and time required for coding and searches, insufficient discrimination capability, and lack of an adequate scheme for ordering the descriptive codes.

[1] Wegstein, J. H., A Semi-automated Single Fingerprint Identification System, NBS Tech. Note 481. (Apr. 1969), for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for 30 cents. Other NBS fingerprint classification research is described in, Computer-oriented fingerprint descriptors, NBS Tech. News Bull. **52**, No. 8, 180–182 (Aug. 1968).

CONFERENCE & PUBLICATION *Briefs*

HANDBOOK OF MATHEMATICAL FUNCTIONS PASSES 100 000 MARK

On August 18, 1969, in a ceremony unusual even for the city of Washington, honor was bestowed on a scientific book, the phenomenally successful *Handbook of Mathematical Functions* [1] and on those who made it possible.

In the brief but significant ceremony, held in the Treaty Room of the Executive Office Building adjoining the White House, the 100 000th copy of the *Handbook* to come from the presses was presented to Presidential Science Advisor Lee A. DuBridge by Myron Tribus, Assistant Secretary of Commerce for Science and Technology. A. V. Astin, Director of the National Bureau of Standards, which publishes the volume, outlined the history of the project in which he acknowledged the cooperation and support, among others, of the National Science Foundation and the National Academy of Sciences. Dr. Astin also presented copies of the book to James L. Harrison, U.S. Public Printer, and Carper W. Buckley, Superintendent of Documents, and to their deputies. Witnessing the ceremony were some of the authors, the surviving editor, Irene A. Stegun (who is also one of the authors), and other dignitaries.

The authors, editor, and others closely connected with the project gathered at a second meeting held later in the afternoon at the National Bureau of Standards in Gaithersburg, Md. At that time, Miss Stegun presented Dr. Astin with copy number 99 999 of the *Handbook*, in recognition of his strong encouragement and support of the project from its very beginning.

At the formal presentation Secretary Tribus, formerly Dean of the Engineering School at Dartmouth, told how he heard of it, and of the constant use he had to make of it. He considered it beyond question "the best of its kind."

In accepting the 100 000th copy, Dr. DuBridge said that the success of the *Handbook* was a tribute to the role of mathematics in a technological society. He cited the design of machines to stamp metal parts for automobiles, the working out of the structure of a protein molecule, and the sending of a spacecraft to Mars, among other examples, to show the essential part played by mathematical functions over the whole range of scientific research. In his closing remarks, he termed the *Handbook* "a precious possession and a symbolic possession, because of its symbolism of what really makes a modern nation possible."

History of the Handbook

Preparation of the *Handbook*, and the steps leading up to it, constitute a major cooperative endeavor, according to Dr. Astin, typical of NBS activities in general. Although 21 of the book's 27 authors were NBS staff members, all phases of the project were discussed with expert makers and users of mathematical tables, and the preparation was carried out under the guidance of a committee, chaired by Philip M. Morse of MIT, named by the National Academy of Sciences–National Research Council. The Handbook project was a natural extension of the Mathematical Tables Project, supported by the Works Progress Administration of New York City. This was a major effort in table making centered at NBS which in the years 1938–1948 produced a collection of 40 large volumes of mathematical tables.

But besides the large tables of individual functions, scientists wanted something more compact and versatile—a collection, if possible within a single volume, of shorter tables of many different functions. Such collections had been prepared in the past and their value was undisputed. Perhaps the most widely used was the *Functionentafeln* of Jahnke and Emde, but by the 1940's it was felt that a new attempt was in order. The tables had to be more extensive, there had to be more of them, and they needed more decimal places for greater accuracy. Moreover, the character of the tables had to reflect the existence and increasing influence of the electronic computer.

The idea of preparing such a volume was broached in 1948 by John Curtiss, Chief of the NBS Mathematics Division. The idea was then elaborated and discussed within NBS and at two major conferences, one in 1952 sponsored by NBS, and another in 1954, sponsored by the National Science Foundation and MIT. Full scale work began when NSF transferred funds to NBS in September 1956 and collaboration began between NBS mathematicians, headed by Milton Abramowitz, and the NAS–NRC committee which, besides Prof. Morse, included A. Erdelyi, M. C. Gray, N. C. Metropolis, J. B. Rosser, H. C. Thacher, Jr., John Todd, C. B. Tompkins, and J. W. Tukey.

In the course of the ceremonies, Dr. Abramowitz was frequently mentioned. He not only drew up the first outline for the *Handbook*, but contributed substantially to its contents, and served as Editor until his untimely death in 1958. In recognition of his devoted efforts, Dr. Abramowitz is listed as Editor jointly with Miss Stegun, who was named his successor.

The completed *Handbook*, first published in 1964, is a volume of 1060 pages divided into 29 chapters written or co-authored by 27 individuals. It contains 180 mathematical tables of which one-third are new, one-third based

on existing NBS tables, and one-third derived from other sources.

Besides the numerical tables, the chapters generally contain graphs of the functions, polynomial or rational approximations for automatic computers, and statements of the principal mathematical properties of the tabulated functions, particularly those of computational importance. Many numerical examples are given to illustrate the use of the tables or the computation of function values which lie outside their range. The use of auxiliary tables makes each page of a table in the *Handbook* equivalent of many pages in an ordinary table.

The *Handbook* is now in its seventh printing and the demand for it shows little sign of tapering off. Suggestions have been made for a supplementary volume to explain the newer techniques for exploiting the tables, but action along these lines has not yet been taken.

Myron Tribus, Assistant Secretary of Commerce for Science and Technology, examines the 100 000th copy of the NBS Handbook of Mathematical Functions. *Lee A. DuBridge, Presidential Science Advisor, to whom the copy was presented (at left), and Allen V. Astin, NBS Director, look on.*

SCHEDULED NBS-SPONSORED CONFERENCES

Each year NBS sponsors a number of conferences covering a broad range of topics in science and technology. The conferences listed below are either sponsored or cosponsored by the NBS and will be held at the Bureau's Gaithersburg, Md., facility unless otherwise indicated. These conferences are open to all interested persons unless specifically noted. If no other address is given, inquiries should be sent to the person indicated below in care of Special Activities Section, Room A600, Administration Building, National Bureau of Standards, Washington, D.C. 20234.

Conference on Image Storage and Transmission for Libraries. Dec. 1–3. Cosponsors: Federal Library Committee; Lister Hill National Center for Biomedical Communication; COSATI (Panel on Information Sciences Technology). Contact: Madeline Henderson (NBS Center for Computer Sciences and Technology).

Twelfth Scintillation and Semiconductor Counter Symposium. Mar. 11–13, 1970. Cosponsors: IEEE (Nuclear Science Group); Atomic Energy Commission. Contact: Louis Costrell (NBS Center for Radiation Research).

Performance of Masonry Structures. Mar. 16–18, 1970. Cosponsors: National Concrete Masonry Association; Structural Clay Products Institute. Contact: Robert Dikkers (NBS Building Research Division).

Silicon Device Processing. June 2–3, 1970. Cosponsor: American Society for Testing and Materials (Committee F–1). Contact: C. P. Marsden (NBS Electronic Technology Division).

1970 Conference on Precision Electromagnetic Measurements. June 2–5, 1970. Cosponsors: IEEE (Group on Instrumentation and Measurement); International Scientific Radio Union (U.S. Commission 1). Contact: George Goulette, Bureau of Continuation Education, University of Colorado, Boulder, Colo. 80302. To be held at NBS in Boulder, Colo.

[1] Abramowitz, M., and Stegun, I., Ed. **Handbook of Mathematical Functions**, Nat Bur. Stand. (U.S.), Appl. Math. Series 55, 1964. Available from the U.S. Government Printing Office, Superintendent of Documents, Washington, D.C. 20402, for $6.50.

THERMAL CONDUCTIVITIES OF HYDROGEN

NEW, ABSOLUTE THERMAL CONDUCTIVITY MEASUREMENTS on both normal (75 percent ortho, 25 percent para) and parahydrogen (99.8 percent para) at temperatures ranging from 17 to 200 K and at pressures up to 10 MN/m^2 (100 atm) have been made at the NBS Institute for Basic Standards. The measurements, with an uncertainty of less than 2 percent, were made by H. M. Roder and D. E. Diller [1] of the Boulder, Colo., laboratories, and represent the final part of a ten-year program to determine the physical properties of hydrogen.

Hydrogen has long been recognized as an ideal fuel for chemical rocket engines and an ideal propellant for nuclear rocket engines. Approximately ten years ago the NBS Cryogenics Division began a program to determine the physical properties of compressed gaseous and liquid hydrogen. Much of this work was sponsored by the NASA

Space Nuclear Propulsion Office because of its need for precise data on hydrogen's physical properties in the design of space vehicle propulsion and propellant control systems. In this decade-long program, NBS engineers and scientists have accurately measured PVT, specific heat, velocity of sound, dielectric constant, refractive index, and viscosity coefficients at temperatures between 14 and 100 K and at pressures up to 35 MN/m^2. The measurements on thermal conductivity now complete the program.

Flat-Plate Calorimeter

A guarded flat-plate calorimeter acting as a thermal conductivity cell was used to determine the thermal conductivities. This device was specifically designed to make accurate, absolute, steady-state measurements in accordance with the Fourier law, which states that "the rate of heat flow at a given point in a body is proportional to the area of the cross section and the temperature gradient."

Heat flow in the calorimeter was from a hot plate, through the fluid being measured, to a cold plate. Flow direction was ensured by thermal guards. The hot plate and the thermal guards were made of electrolytic tough pitch (ETP) copper, a high purity material selected because of its excellent thermal conductivity. The sample holder was made of a beryllium-copper alloy. Electrical heat input was determined by conventional potentiometric techniques. The cell constant was determined for each thermal conductivity measurement by using the calorimeter as a shielded, three-terminal capacitor.

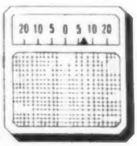
The temperature of both plates was determined with a precision of about 0.001 K by platinum resistance thermometers accurately calibrated at NBS. The temperature difference between the plates was about 1.0 K for gaseous hydrogen and about 0.2 K for liquid hydrogen. This measurement had the greatest uncertainty—about 0.001 K—which led to a nominal uncertainty of less than 2 percent in the thermal conductivities.

Measurement Results

Some 250 new measurements on the gaseous and liquid phases of normal and parahydrogen were taken. The thermal conductivities were first plotted as a function of pressure along isotherms. This is the property diagram that appears most frequently in engineering texts because it can be readily used to estimate the conductivity at a selected temperature and pressure. In the case of hydrogen, however, many of the curves cross and the temperature dependence changes sign several times. Accordingly, an improved graphical presentation was used, plotting the conductivities as a function of density rather than pressure.

It was found that the temperature dependence of the thermal conductivity of liquid hydrogen at fixed density is positive and much larger than for other simple liquids (except helium). For example, at a fixed density of 0.07 g/cm^3 the thermal conductivity increases about 50 percent between 20 and 40 K. It was also found that the thermal conductivity of saturated liquid parahydrogen increases with temperature between the triple point (13.8 K) and about 25 K, whereas for most liquids the thermal conductivity decreases with temperature between the triple point and the critical point.

[1] Diller, D. E., and Roder, H. M., Thermal Conductivity Measurements on Fluid Hydrogen at 17 to 200 K and Pressures to 10 MN/m^2, chapter in Advances in Cryogenics, Vol. 15 (Plenum Press, New York, N.Y., 1970).



STANDARDS AND CALIBRATION

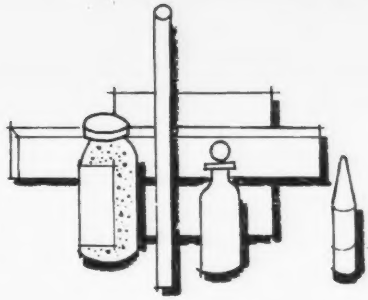
STANDARD FREQUENCY AND TIME BROADCASTS

High-frequency radio stations WWV (Fort Collins, Colo.) and WWVH (Maui, Hawaii) broadcast time signals on the Coordinated Universal Time (UTC) system as coordinated by the Bureau International de l'Heure (BIH), Paris, France. These NBS time signals, UTC(NBS), are maintained within 5 microseconds of the corresponding time signals of the U.S. Naval Observatory, UTC(USNO). The UTC pulses occur at intervals that are longer than one coordinate second by 300 parts in 10^{10} during 1969, due to an offset in carrier frequency coordinated by BIH. To maintain the UTC scales in close agreement with the astronomers' time, UT2, phase adjustments are made at 0000 hours Greenwich Mean Time (GMT) on the first day of a month as announced by BIH. *There will be no adjustment made on December 1, 1969.*

The low-frequency radio station WWVB (Fort Collins, Colo.) broadcasts seconds pulses without offset to make available to users the standard of frequency so that absolute frequency comparisons may be made directly, following the Stepped Atomic Time (SAT) system. Step time adjustments of 200 ms are made at 0000 hours GMT on the first day of a month when necessary. BIH announces when such adjustments should be made in the scale to maintain the seconds pulses within about 100 ms of UT2. *There will be no adjustment made on December 1, 1969.*

NBS obtains daily UT2 information from forecasts of extrapolated UT2 clock readings provided by the U.S. Naval Observatory with whom NBS maintains close cooperation.

STANDARD REFERENCE MATERIALS



Standard Reference Materials are well-characterized materials disseminated by NBS to be used to calibrate and evaluate measuring instruments, methods, and systems or to produce scientific data that can be referred readily to a common base. The materials [1] are certified for chemical composition or for a particular physical or chemical property. They are used on-site in science and industry to calibrate instruments and methods used in production and quality control of raw materials, chemicals, metals, ceramics, fuels, and radioactive nuclides in manufacturing processes and in research.

GOLD COATING WEIGHT (THICKNESS) STANDARDS

Four new Standard Reference Materials (SRM's) for the coating weight of gold on Fe-Ni-Co glass sealing alloy have been made available. These standards, SRM's 1371, 1372, 1373, and 1374, have nominal coating weights of 1.5, 3, 6, and 14 mg/cm^2, which are equivalent to 30, 60, 120, and 280 microinch thicknesses of pure gold. They may be purchased separately or in combinations as indicated in the following table:

SRM	*Nominal Coating Weight (mg/cm ^{2})*	*Nominal Thickness (microinch)*	*Price* [2]
1371	1.5	30	$48
1372	3.0	60	48
1373	6.0	120	48
1374	14.0	280	48
1381	one each of 1371 and 1372		73
1382	one each of 1372 and 1373		73
1383	one each of 1373 and 1374		73
1398	one each of 1371, 1372, 1373, and 1374		123

The sealing alloy, conforming to ASTM Designation F 15, nominally 53 percent iron, 29 percent nickel, and 17 percent cobalt, is commonly used for making hermetic seals to glass in electronic applications.

These coating thickness standards are 15 mm square. They are to be used to calibrate coating thickness gages of the beta-backscatter type and x-ray fluorescence methods specifically to measure the thickness of gold coatings on Fe-Ni-Co glass sealing alloy. They are suitable for the direct calibration of equipment used to measure weight per unit area of gold coating of equivalent purity. If the proper correction is made for the density of the gold being measured, the instruments can be calibrated in terms of the thickness.

The gold coating is electrodeposited and assays a minimum of 99.9 percent gold. The substrate is not buffed prior to gold plating but plated with the mill finish. X-ray fluorescence techniques are used to measure the thickness of the gold coating relative to NBS gold coating materials for which the average weights per unit area are determined by weight and area measurements.

The stated weight of gold per unit area is certified to be within 5 percent of the actual weight per unit area at the center of the specimen and of the average weight per unit area over the 15 mm square. An equivalent thickness is given, but not certified. This thickness is calculated assuming that the gold is pure and has a density of 19.3 g/cm^2, the density of pure gold.

These new SRM's complement the NBS gold on nickel coating thickness SRM's already available.

The Office of Standard Reference Materials will, on documented needs, make available other coating weight or coating thickness standards. The new standards will depend in part on information provided by current and potential users. Pertinent information regarding new coating standards requirements should be sent to the Office of Standard Reference Materials, National Bureau of Standards, Washington, D.C. 20234, Attention: Fielding Ogburn.

Information about a specific thickness standard need should include:

1. Coating materials required
2. Coating thickness
3. Substrate material
4. Type of thickness measuring instrument, such as beta-backscatter, magnetic, or Eddy current
5. Anticipated need (number of units per year).

STAINLESS STEEL STANDARDS

Two stainless steel SRM's recently were issued. The first, SRM 160b, chip form, is a renewal designed primarily for checking chemical methods of analysis. The second, SRM 1155, is a new standard in solid form designed primarily for the calibration of optical emission

and x-ray spectroscopic methods of analysis. Both SRM's were prepared from the same lot of AISI 316-type stainless steel, one of the important grades of the austenitic stainless steels. The new standards enable systematic errors now suspected of existing between chemical and spectroscopic methods of analysis to be minimized or eliminated. The availability of two SRM's of the same material, but in two different forms will aid in this task.

The material for the two SRM's was prepared at the Duquesne Works of the U.S. Steel Corp., Pittsburgh, Pa., as rods 12.7 cm (5 in) in diameter and 91 cm (36 in) long. These were later cut at NBS to a diameter of 6.4 cm (2½ in) to provide the chip standard, SRM 160b. The remaining cores were then swaged to oversize rods at the Naval Research Laboratory and finally centerless ground to size 3.2 cm (1¼ in) in diameter at NBS. Homogeneity testing and analyses for provisional certification were performed in the NBS Analytical Chemistry Division. Each standard is provisionally certified for carbon, manganese, phosphorus, sulfur, silicon, copper, nickel, chromium, vanadium, molybdenum, cobalt, and lead. A nitrogen value for SRM 160b is also given.

SRM 160b is available in units of 150 grams for $33; SRM 1155 costs $65 for each disk 3.2 cm (1¼ in) in diameter and 1.9 cm (¾ in) thick.[2]

BLAST FURNACE AND WHITE IRON STANDARDS

Five new, white chill-cast iron SRM's have been certified. The compositions of two of these, SRM's 1143 and 1144, have been specially designed for production control of blast furnace iron. The others, SRM's 1147, 1148, and 1149, simulate important gray iron compositions, but have been prepared with a white iron structure by means of rapid chill-casting and the addition of strong carbide stabilizers.

These new SRM's were prepared and issued to meet a serious shortage of standards in the cast iron industry for production control and customer acceptance. Designed primarily for calibration in optical emission and x-ray spectrometric methods of analysis, these standards are issued in the form of segments approximately 3.2 cm (1¼ in) square and 1.3 cm (½ in) thick. The unit price for each of these SRM's is $65.[2]

The certification and issuance of these white iron standards is the culmination of a cooperative program between industry and NBS that included the planning, preparation, homogeneity testing, and analysis of these standards. The material for the standards was melted and cast at the American Cast Iron Pipe Co., Birmingham, Ala.; homogeneity testing was performed at the General Motors Corporation Research Laboratories in Warren, Mich.; and analyses for the provisional certification were performed by members of the Ductile Iron Society under the direction and coordination of W. R. Kennedy, American Cast Iron Pipe Co. Cooperating members of the Ductile Iron Society include the American Cast Iron Pipe Co., the Ford Motor Co., the International Nickel Co., and the U.S. Pipe and Foundry Corp. The standards have been issued initially with a Provisional Certificate of Analysis that provides values for carbon, manganese, phosphorus, sulfur, silicon, copper, nickel, chromium, vanadium, molybdenum, titanium, arsenic, and tellurium.

These new standards should be of considerable interest in supplementing and extending the elements and concentration ranges for white cast iron standards previously available from NBS.

The final certification for each of the five standards should be available in about six months.

[1] For a complete list of Standard Reference Materials available from NBS, see **Standard Reference Materials: Catalog and Price List of Standard Materials Issued by the National Bureau of Standards**, NBS Spec. Publ. 260 (July 1, 1969 ed.) for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for 45 cents. Insert sheets which update Spec. Publ. 260 are supplied to users on request.

[2] These standards may be purchased for the price indicated from the Office of Standard Reference Materials, Rm. B308, Chemistry Bldg., National Bureau of Standards, Washington, D.C. 20234.

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Technical News Bulletin, Volume 53, No. 10, October 1969, 30 cents. Annual subscription: Domestic, $3; foreign, $4. Available on a 1-, 2-, or 3-year subscription basis.

Journal of Research of the National Bureau of Standards

Section A. Physics and Chemistry. Issued six times a year. Annual subscription: Domestic, $9.50; foreign, $11.75. Single copy price varies.

Section B. Mathematical Sciences. Issued quarterly. Annual subscription: Domestic, $5; foreign, $6.25. Single copy, $1.25.

Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: Domestic, $5; foreign, $6.25. Single copy, $1.25.

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**Publications with prices indicated may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (foreign: one-fourth additional). The NBS nonperiodical series are also available from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151. Reprints from outside journals and the* NBS Journal of Research *may often be obtained directly from the authors.*

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U.S. Government Research & Development Reports Index. Semimonthly index to preceding; arranged by subject, personal author, corporate author, contract number, and accession/report number. Annual subscription (24 issues): Domestic, $22; foreign, $27.50. Single copy, $3.

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MISSION AND FUNCTIONS OF THE DEPARTMENT OF COMMERCE

"to foster, serve and promote the nation's economic development and technological advancement"

THE NATIONAL ECONOMIC GOAL

Sustained maximum growth in a free market economy, without inflation, under conditions of full employment and equal opportunity

THE DEPARTMENT OF COMMERCE

The historic mission of the Department is "to foster, promote and develop the foreign and domestic commerce" of the United States. This has evolved, as a result of legislative and administrative additions, to encompass broadly the responsibility to foster, serve and promote the nation's economic development and technological advancement. The Department seeks to fulfill this mission through these activities:

Participating with other government agencies in the creation of national policy, through the President's Cabinet and its subdivisions.

- **Cabinet Committee on Economic Policy**
- **Urban Affairs Council**
- **Environmental Quality Council**

Promoting progressive business policies and growth.

- **Business and Defense Services Administration**
- **Office of Field Services**

Assisting states, communities and individuals toward economic progress.

- **Economic Development Administration**
- **Regional Planning Commissions**
- **Office of Minority Business Enterprise**

Strengthening the international economic position of the United States.

- **Bureau of International Commerce**
- **Office of Foreign Commercial Services**
- **Office of Foreign Direct Investments**
- **United States Travel Service**
- **Maritime Administration**

Assuring effective use and growth of the nation's scientific and technical resources.

- **Environmental Science Services Administration**
- **Patent Office**
- **National Bureau of Standards**
- **Office of Telecommunications**
- **Office of State Technical Services**

Acquiring, analyzing and disseminating information concerning the nation and the economy to help achieve increased social and economic benefit.

- **Bureau of the Census**
- **Office of Business Economics**

NOTE: This schematic is neither an organization chart nor a program outline for budget purposes. It is a general statement of the Department's mission in relation to the national goal of economic development.

JULY 1969

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